TITLE OF THE INVENTION

FOCUS MONITOR METHOD AND MASK

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the

benefit of priority from prior Japanese Patent

Application No. 2003-046236, filed February 24, 2003,

the entire contents of which are incorporated herein by

reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a focus monitor method

and mask suitable to setting focus conditions in a

projection exposure apparatus relevant to the

manufacture of semiconductor devices and LCD devices

and the like.

2. Description of the Related Art

Among techniques of measuring a defocus amount

with high accuracy and simplicity, a method as

described hereinafter is known (for example, as

disclosed in Japanese Unexamined Patent Application

Publication No. 2001-100392). According to this

technique, a focus monitor mask in which a pattern

(focus monitor pattern) capable of detecting focus

variations is disposed, a line width of a post-transfer

monitor mark is measured by using a linewidth measuring

apparatus (optical linewidth measuring apparatus, such

as an SEM or the like) or a linewidth measuring

functionality built in an exposure apparatus itself,
a variation amount of focus is obtained thereby.

According to the focus monitor pattern described
in the above patent publication, the defocus amount
5   independently from exposure can be measured even when
the exposure. However, depending on a set exposure,
a sensitivity of calibration curve can undesirably
varied due to the exposure. The set exposure is set by
a layer of a device. However, when a large difference
10   takes place between set exposures for layers, there can
occur a case in which the large deviation from
an optimal exposure for the focus monitor pattern
(the exposure range in which exposure dependency is law
in the calibration curve). To address such a problem,
15   it is ideal to optimally design the focus monitor
pattern by the layer. However, the creation of the
pattern is a time-and-cost consuming process, so that
a more simple technique has been demanded.

As described above, the technique gives rise to
20   the problem in that when exposure is performed with the
exposure largely deviating from the optimal exposure
for the focus monitor pattern, the exposure dependency
takes place in the calibration curve, resulting in
a large tolerance of the amount of the defocus to be
25   obtained.

BRIEF SUMMARY OF THE INVENTION

According to one aspect of the present invention,

there is provided a focus monitor method comprising:
preparing a mask comprising a first and second focus
monitor patterns and an exposure monitor pattern, the
first and second focus monitor patterns being used to

5   form first and second focus monitor marks having
dimensions variable depending on a defocus amount on a
wafer, a defocus amount dependency of dimension of the
first focus monitor mark being different form a defocus
amount dependency of dimension of the second focus

10   monitor mark, and the exposure monitor pattern being
used to form exposure meters having dimensions variable
depending on an effective exposure on the wafer;
obtaining a exposure dependency of a relationships
between a dimensions of the first and second focus

15   monitor marks and the defocus amount; forming the first
and second focus monitor marks and exposure monitor
marks on the wafer by using the mask; measuring a
dimension of the exposure monitor marks to obtain an
effective exposure; selecting a relationship between

20   the dimensions of the first and second focus monitor
marks and the defocus amount corresponding to the
effective exposure in accordance with the obtained
effective exposure and the exposure dependency of the
relationships between the dimension of the first and

25   second focus monitor marks and the defocus amount;
measuring a dimension of the first and second focus
monitor marks; and obtaining a defocus amount in

accordance with the measured dimensions of the first
and second focus monitor marks and the relationship
between the dimension of the first and second focus
monitor marks and the defocus amount corresponding to
5   the effective exposure.

According to one aspect of the present invention,
there is provided a focus monitor method comprising:
preparing a first mask comprising a first and second
focus monitor patterns, the first and second focus
10   monitor patterns being used to form first and second
focus monitor marks having dimensions variable
depending on a defocus amount are formed on a wafer, a
defocus amount dependency of dimension of the first
focus monitor mark being different form a defocus
15   amount dependency of dimension of the second focus
monitor mark; forming the first and second focus
monitor marks on the wafer with a plurality of
exposures; obtaining a first relationships between a
dimension of the first and second focus monitor marks
20   and a defocus amount for each of a plurality of
exposure dose; obtaining a nonuniformity amount of the
first relationships due to a variation in the exposure;
obtaining a second relationship between the first
relationships and the exposure when the obtained
25   nonuniformity amount is greater than a predetermined
value; preparing a second mask comprising third and
fourth focus monitor patterns and an exposure monitor

pattern, the third and fourth focus monitor pattern
being used to form third and fourth focus monitor marks
having dimensions variable depending on a defocus
amount are formed on the wafer, a defocus amount

5   dependency of dimension of the first focus monitor mark
being different form a defocus amount dependency of
dimension of the second focus monitor mark, and the
exposure monitor pattern being used to form exposure
meter having dimensions variable depending on an

10   effective exposure on the wafer; obtaining a third
relationship between the dimension of an exposure meter
and the exposure; forming the third and fourth focus
monitor marks and the exposure meters on the wafer by
using the second mask; measuring the dimension of the

15   exposure meter; obtaining an effective exposure from
the measured dimension of the exposure meter and the
third relationship; selecting a fourth relationship
between the dimension of the third and fourth focus
monitor marks and the defocus amount corresponding to

20   the effective exposure from the obtained effective
exposure and the second relationship; measuring the
dimension of the third and fourth focus monitor marks;
and obtaining a defocus amount in accordance with the
measured dimension of the third and fourth focus

25   monitor marks and the fourth relationship.

    According to one aspect of the present invention,
there is provided a mask comprising: a device region

wherein a device pattern is formed; a first pattern region having at least one first monitor pattern which is constituted by a first opening surrounded by a shielding portion or constituted by the shielding

5 portion surrounded by the first opening; a second pattern region having at least one second monitor pattern which is constituted by a second opening surrounded by a translucent film or constituted by the translucent film surrounded by the second opening, and

10 is capable of giving a phase difference to an exposure light passing through the translucent film relative to an exposure light passing through the second opening; and a third pattern region including a plurality of blocks intermittently or continuously arranged in one

15 direction each including a shield portion and transmission portion arranged in a constant width p incapable of being resolved in a projection exposure apparatus in the direction and having a monotonously changing dimension ratio of the shield portion to the

20 transmission portion of the block in the direction, wherein one of the first pattern region and the second pattern region is formed at least in the device region.

According to one aspect of the present invention, there is provided a mask comprising: a device region

25 wherein a device pattern is formed; a device region wherein a device pattern is formed; a first pattern region comprises at least one first monitor pattern

which is constituted by a first translucent film
surrounded by a first opening portion or constituted by
the first opening portion surrounded by the first
translucent film, and is capable of giving a first

5   phase difference to an exposure light passing through
the first translucent film relative to an exposure
light passing through the first opening; a second
pattern region comprises at least one second monitor
pattern which constituted by a second translucent film

10   surrounded by a second opening portion or constituted
by the second opening portion surrounded by the second
translucent film, and is capable of giving a second
phase difference different from the first phase
difference to an exposure light passing through the

15   second translucent film relative to an exposure light
passing through the second opening; and a third pattern
region including a plurality of blocks intermittently
or continuously arranged in one direction each
including a shield portion and transmission portion

20   arranged in a constant width p incapable of being
resolved in a projection exposure apparatus in the
direction and having a monotonously changing dimension
ratio of the shield portion to the transmission portion
of the block in the direction, wherein one of the first

25   pattern region and the second pattern region is formed
at least in the device region.

    BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

FIG. 1 is a plan view schematically showing the structure of a mask according to an embodiment of the invention;

FIG. 2A is a plan view showing a focus monitor, and FIG. 2B is a cross sectional view along with the line A-A' showing FIG. 2A;

FIG. 3 shows exposure dependency of the relationship between a dimensional difference in the longitudinal dimension of rhombic mark 211, 221 and the defocus amount;

FIG. 4 is a plan view showing the structure of an exposure monitor pattern;

FIG. 5 is a view showing the relationship between the length of each exposure meter and the exposure;

FIG. 6 is a flowchart showing a part of a defocus-amount measuring method of an embodiment according to the invention;

FIG. 7 is a diagram showing exposure dependency of the relationship (calibration curve) between the dimensional difference and the defocus amount;

FIG. 8 is a coefficient b with respect to the exposure;

FIG. 9 is a flowchart of the defocus-amount measuring method of an embodiment according to the invention;

FIG. 10 is a plan view showing focus nonuniformity in a wafer plane, obtained as a result of application

of the embodiment method;

FIG. 11 is a plan view showing focus nonuniformity in a wafer plane, obtained as a result of a conventional method;

FIGS. 12A to 12C are plan views showing the structure of a modified example of a mask; and

FIG. 13A is a plan view showing a focus monitor, and FIG. 13B is a cross sectional view along with the line A-A' showing FIG. 13A.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments according to the invention will be described hereinafter with reference to the drawings.

FIG. 1 is a plan view schematically showing the structure of a mask according to an embodiment of the invention. Referring to FIG. 1, in a mask 100, a focus monitor pattern 200 and an exposure monitor pattern 300 for measurement of an effective exposure are disposed close to each other. The focus monitor pattern 200 and the exposure monitor pattern 300 are formed in a dicing line 101 around a device region 102 where device patterns are formed.

The structure of the focus monitor pattern will be described by using FIGS. 2A and 2B. FIG. 2A is a plan view showing the structure of the focus monitor pattern, and FIG. 2B is a cross-sectional view of the A-A' section of FIG. 2A. In the drawings, numeral 201 denotes a transparent substrate of glass or the like,

numeral 202 denotes a translucent film of SiO_2 or the like, and numeral 203 denotes a light shield film of Cr or the like.   Rhombic marks 211 (first opening portions) each surrounded by the light shield film 203 are formed in a first pattern region 210.   Rhombic marks 221 (second opening portion) each surrounded by the translucent film 202 are formed in a second pattern region 220.   The translucent film 202 has a transmittance of 6% for exposure light and has the effect of shifting the phase thereof by 180 degrees.

Thus, the rhombic marks 211 are formed in the first pattern region 210, and the rhombic marks 221 are formed in the second pattern region 220.   More specifically, five rhombic marks 211 and five rhombic marks 221 are formed, respectively, at a constant pitch in the regions 211 and 220.   As shown in the plan views of FIGS. 2A and 2B, the rhombic marks 211 and 221 are each formed such that, in terms of the wafer, the length thereof along the x-axis is 12 μm, the length along the Y-axis is 0.18 μm, and the pitch therebetween is 0.36 μm.   The substrate in the portion having the rhombic marks 221, that is, the second opening portions is concavely formed to a depth of, for example, 124 nm so that the phase difference of 90 degrees imparted between exposure light passing through the translucent film 202 and exposure light passing through the opening 221.   An appropriate

exposure for the focus monitor pattern is 7.5 mJ/cm^2.

FIG. 3 shows exposure dependency of the relationship between a dimensional difference in longitudinal dimensions of focus monitor marks, which

5　are formed by transfer of the rhombic marks 211 and 221, and the defocus amount.　More specifically, shown in FIG. 3 is the relationship between the dimensional difference and the defocus amount in the case where the exposure was varied by ±1%, ±5%, and ±10% from the

10　value of 7.5 mJ/cm^2 set as the center value.　As is shown in FIG. 3, it can be verified that even when the exposure is caused variable in the range of ±10%, the exposure does not substantially vary.　Consequently, even when the exposure has been fluctuated by

15　7.5 mJ/cm^2, the defocus amount can be measured with high accuracy.

In the structure shown in FIG. 2A, focus monitor patterns of two types different in the array direction are formed.　When a large aberration occurs with an

20　optical system of the exposure apparatus, there can occur a case where marks are formed in different sizes depending on the array direction of the patterns. In this case, an average of amounts of defocus obtained through the individual focus monitor marks is used as

25　a defocus amount for measurement.　This manner consequently enables the influence of the optical-device aberration can be restrained.

The structure of the exposure monitor pattern will now be described hereinbelow by using FIG. 4. FIG. 4 is a plan view showing the structure of the exposure monitor pattern.

As shown in FIG. 4, in the exposure monitor pattern 300, transmissive portions 301 and shield portions 302 are individually arrayed in blocks each having a width p, which are unresolvable with the exposure apparatus. A plurality of blocks are successively arrayed in the array direction of the transmissive portions 301 and the shield portions 302. In the array direction, a duty ratio between the transmissive portion 301 and the shield portion 302 monotonically varies. The plurality of blocks may be intermittently arrayed.

Upon irradiation of the exposure monitor pattern with illumination light, the optical intensity distribution of diffractive light through the exposure monitor pattern over the substrate surface exhibits a monolithic reduction or a monolithic increase that does not depend on the focus position.

A case is now assumed where a mask desired to be used to monitor an effective exposure is set in an exposure apparatus with a number of openings NA, a coherent factor σ, and a wavelength λ. In this case, according to diffraction theory, the conditions of the width p (wafer-based dimension) of the block

unresolvable with the apparatus

$$1/P \geq (1+\sigma)NA/\lambda$$

With a photoresist film having been formed over the substrate, latent images (exposure meters)

5   corresponding to gradient distributions of the exposure independent of the focus condition are formed over the photoresist film. The exposure is measured by measuring the length on one side of a pattern obtained through development of the latent image, which has been

10   formed on the photoresist film, or development of the photoresist film. FIG. 5 shows the relationship between the length of each of the exposure meters and the exposure.

The dimensions of measured focus monitor mark,

15   the defocus amount thereof, and the exposure can be expressed by the following equation:

$$L = \sum_{n=0} a_n E_n * F + \sum_{n=0} a'_{n=0} E^n$$

where, L is a dimensional difference between the

20   longitudinal dimensions of the mark in the first pattern region 210 and the mark in the second pattern region 220; F is a defocus amount; E is an exposure; a is a coefficient; and n is an integer phase difference.

Accordingly, when the dimensions of focus monitor

25   patterns to be measured are fluctuated due to the exposure, the calibration curve is first eliminated by using the effective exposure acquired from the

exposure meter, and exposure dependency of the calculated defocus amount can then be eliminated.

First, a determination is made whether a correction of a calibration curve (the relationship between the dimensional difference and the defocus amount) corresponding to the effective exposure is necessary for a set exposure. As a result, if the correction of the calibration curve is determined necessary, the relationship between the effective exposure and the calibration curve should be obtained. A method for the above will be described with reference to FIG. 6. FIG. 6 is a flowchart showing a part of a defocus-amount measuring method of an embodiment according to the invention.

The method performs exposure for patterns formed over the mask by applying a plurality of exposures and then investigate the exposure dependency of a calibration curve (step S101).

In practice, exposure was performed with the exposure varied in the range of -10% to +10% from the central value set to 30 mJ/cm^2. FIG. 7 is a graph showing the exposure dependency of the relationship between the dimensional difference and defocus (calibration curve). More specifically, the graph shows the relationship between the dimensional difference and the defocus amount in the event that the exposure was varied at ratios of -10%, -5%, -1%, 0%

(30 mJ/cm^2), +1%, +5%, +10% from 30 mJ/cm^2 set as the central value. The results shown in FIG. 7 teaches that the calibration curve is variable depending on the set exposures (straight portions in the graph is variable).

Conditions for obtaining the calibration curve are shown below. On a wafer, there are formed a coating-type reflection preventive film having a thickness of 60 nm and a 0.4 μm thick photoresist film of a chemical amplification positive type. The reflection preventive film and the photoresist film are formed by using a spin coating process.

The specifications of an exposure apparatus used are inclusive of: reduction ratio of an exposure apparatus = 1/4; exposure light wavelength = 248 nm; NA = 0.6; coherence factor σ = 0.75; and ring zone shielding factor ε = 0.67. Exposure monitor patterns used with this exposure apparatus are characterized as: pitch = 0.19 μm; width = 2 μm; and space size (in terms of the wafer) = continually varied by 0.625 nm.

Subsequently, the wafer after completion of the exposure underwent post exposure baking (PEB) at 100°C for 90 minutes, followed by imagewise development for 60 seconds using an alkaline developing solution of 0.21N.

Subsequently, the dimension of these the two types of wedge-shaped patterns formed over the wafer

processed as described above was dimensionally measured
by using an optical linewidth measuring apparatus to
obtain a difference between a pattern dimension L' and
a pattern dimension L.   The pattern dimension L'

5   represents the x-axis directional dimension of the
wedge-shaped pattern formed by the transfer of the mark
in the second pattern region 220.   The pattern
dimension L represents the x-axis directional dimension
of the wedge-shaped pattern formed by the transfer of

10   the mark in the first pattern region 210.   From a
monolithic increase in the characteristics of the
dimensional difference with respect to the defocus, the
magnitude of positional deviation of focus can be
obtained together with the sign.

15   Subsequently, after having obtained exposure
dependency of the calibration curve, the method
measures the nonuniformity in the defocus amount due to
exposure nonuniformity (step S102).   As is shown in
FIG. 7, the primary expression "$y = ax + b$" is used to

20   approximate the calibration curve at the each
individual exposure.   Thereby, the method obtains
the nonuniformity in a y-axis intercept ("b") of
each individual approximation expression.   In the
present example case, the nonuniformity is obtained

25   with maximum value derived from the expression "maximum
b_{max} − minimum value b_{min}."   The nonuniformity in the
y-axis intercept is divided by a tilt a.   A resultant

value thus obtained represents the nonuniformity in
the defocus amount caused by exposure nonuniformity.

The method is then determines whether the
nonuniformity thus obtained is less than or equal to
a specification value (step S103). In the present
embodiment, the specification value is 10 nm. In the
case represented by the calibration curve shown in
FIG. 7, the nonuniformity was 50 nm.

If the nonuniformity is less than or equal to the
specification value (as in the case shown in FIG. 3),
the method determines one of the calibration curves,
which having been obtained as described above, to be
the calibration curve at the corresponding exposure
(step S104).

If the nonuniformity is greater than the
specification value, the method obtains the
relationship between the calibration curve and the
exposure(step S105). In the present case, the method
obtains exposure dependencies of coefficients b
obtained in the earlier step. The coefficients b with
respect to the exposures are shown in FIG. 8. The
coefficient b is approximated by a quadratic function.
In the case of FIG. 8, the quadratic function is
"$0.0029x^2 - 0.2081x + 4.4479$."

In the manner described above, the method obtains
data on the necessity of the calibration curve
correction and the relationships between the effective

exposures and the calibration curves.

Referring now to FIG. 9, a description will be made hereinbelow regarding the defocus-amount measuring method in the case where the nonuniformity is greater than the specification value, wherein is risen the necessity of correction of the calibration curve in accordance with the effective exposure. FIG. 9 is a flowchart of the defocus-amount measuring method of an embodiment according to the invention.

A practical wafer is exposed using the mask described above, and focus monitor marks, and exposure meters are thereby formed (step S201). Exposure and development conditions are the same as those described above.

Subsequently, the dimensions of focus monitor marks of the two types and the exposure meter are measured (step S202). The dimensional difference between the focus monitor marks of the two types are obtained. An effective exposure is obtained from the dimension of the exposure meter (step S203).

Calculation is performed by assigning the obtained effective exposure to the above-described x function to thereby obtain the coefficient (step S204). Then, the calibration curve is shifted parallel to the y direction so that the intercept of the calibration curve become equal to the calculated coefficient to thereby correct the calibration curve (step S205).

Although the plurality of calibration curves are present in the case shown in FIG. 7, a calibration curve when the exposure is set to 30 mJ/cm^2 is shifted in the present example.

Subsequently, the method obtains the defocus amount by using the dimensional difference between the focus monitor marks and concurrently using the corrected calibration curve (step S206).

FIG. 10 shows focus nonuniformity in a plane of the wafer, obtained by applying the inventive method. FIG. 11 is a plan view showing focus nonuniformity in a plane of a wafer, obtained by applying the conventional method. The conventional method exhibited systematic distribution, which is considered to have been caused by exposure offsets. As shown in FIG. 10, the embodiment method is designed capable eliminating systematic error considered to have been caused by exposure variations.

According to the embodiment method, the focus monitor pattern and the exposure monitor pattern are formed in the mask, the effective exposure is measured from the dimension of the exposure meter formed in the resist, and the calibration curve is corrected in accordance with the measured effective exposure. Consequently, error in the defocus amount can be reduced even with a set exposure greatly differing from the optimal amount of exposure.

In the present embodiment method, while the focus detection marks are measured using an optical linewidth measuring apparatus disposed independently from the exposure apparatus. However, the marks can be alternatively measured using, for example, a linewidth measuring functionality built in the exposure apparatus itself or a non-optical measuring apparatus such as an SEM. The focus monitor marks may be of any type that is measurable by using the optical linewidth measuring apparatus. For example, the each individual mark need not have a wedge shape with a sharp tip. As long as the mark has a shape with a tip portion formed narrower than the central portion of the mark, the mark exhibits sufficient functionality as a focus monitor mark.

The size and pitch of the focus monitor pattern, the transmittance of the translucent portion, and the width and the pitch of the exposure monitor pattern are not limited only to those of the present embodiment. These factors may be variously modified depending on the exposure conditions employed, thereby enabling the focus detection performance to be even more enhanced.

The focus monitor mark is not limited to that of the tapered pattern, but a mark of a pattern as shown in FIGS. 12A, 12B, and 12C may be used. FIGS. 12A, 12B, and 12C show the structure of the mask; and more specifically, FIG. 12A is a plan view showing the entirety of the mask, FIG. 12B is a plan view showing

the structure of the focus monitor pattern, and

FIG. 12C is a plan view showing the structure of

the device region 102. As shown in FIGS. 12A, 12B,

and 12C, a focus monitor pattern 500 is formed in

a mask 400. The portion of focus monitor marks is

constituted of a first pattern region 510 and a second

pattern region 520. Openings 511 surrounded by a light

shield film 203 is formed in the first pattern

region 510. Openings 521 surrounded by a translucent

film 202 is formed in the second pattern region 520.

Openings 103 surrounded by the light shield film 203

are formed in a device region 102. A pattern of the

device region 102 is an element separation pattern.

In this case, the dimensions of the openings 511

and the openings 521 are not measured, but the

dimensions of the openings 521 and the openings 103 are

each measured. From the dimensional difference between

the two openings 103 and 521, the defocus amount can be

obtained. Meanwhile, the device pattern to be used is

not limited to the illustrated element separation

pattern, but may be any one of various other patterns.

Different from the focus monitor pattern described

earlier, the arrangement may be such that translucent

films are provided in both the first and second pattern

regions though rhombic marks being formed so as to

produce phase differences therein.

For example, as shown in FIG. 13, in a first

pattern region 230 where rhombic marks 231 (first opening portion) are formed, a substrate 201 exposed to the opening portion is partly concavely formed (to a depth of 124 nm, for example). Thereby, light

5   passing through a translucent film 202 in a peripheral portion of the rhombic marks 231 has a phase difference of +90 degrees with respect to light passing through the rhombic marks 231 provided as the opening portion. In a second pattern region 240 where rhombic marks 241

10   (second opening portion) are formed, the substrate 201 exposed to the opening portion is partly concavely formed (to a depth of 372 nm, for example). Thereby, light passing through the translucent film 202 in a peripheral portion of rhombic marks 241 has a phase

15   difference of −90 degrees with respect to light passing through the rhombic marks 241 provided as the opening portion.

     In the embodiments, the first pattern region and the second pattern region share the same translucent

20   film, and different phase differences are imparted to the first pattern region and the second pattern region by concavely forming the transparent substrate in the opening portions. However, different translucent films may instead be used in the first and second pattern

25   regions.

     Moreover, the relationship between the light shield film or the translucent film portion and the

opening portion in the first pattern region 210, 230

may be reversed. More specifically, the structure may

be arranged to have a monitor pattern formed of a

light-shielding film having a rhombic or wedge-shaped

5   light shield film surrounded by an opening portion.

Similarly, the relationship between the translucent

film portion and the opening portion light shield film

or the translucent film portion and the opening portion

in the second pattern region 220, 240 may be reversed.

10   That is, the structure may be arranged to have

a monitor pattern formed of a light-shielding film

having a rhombic or wedge-shaped light shield film

surrounded by an opening portion. Even with any one of

these combined structures being used, effects

15   equivalent to those in the embodiment described above

can be secured.

The present embodiment uses the marks of the

translucent film having the 90-degree phase difference.

However, the phase difference is not limited to

20   90 degrees, and any one of different phase differences

may be selected for use as long as the selected phase

difference causes best-focus positional variations

between the wedge-shaped marks in the light shield film

portion and the wedge-shaped marks in the translucent

25   film portion.

In the present embodiment, while the calibration

curve of the phase-difference focus monitor is assumed

to be the primary straight line, it is not limited to thereto. As long as the characteristics of the calibration curve can be exhibited, various other functions may be used.

5   While the embodiment described above uses the mask, in which the exposure monitor pattern is formed, to determine the necessity/unnecessity of correcting the calibration curve, the embodiment may instead use a mask without the exposure monitor pattern at the time

10   of making the determination.

In the present embodiment, while the marks are disposed on the dicing line of the device mask, as described above, the position is not limited to the dicing line. The focus can be monitored even when,

15   for example, phase-difference focus monitor marks and exposure monitor marks are disposed in predetermined positions and are used, and a test mask including these marks is used.

Additional advantages and modifications will

20   readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the

25   spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.